INFORMATION TECHNOLOGY PROGRAM
STRATEGIC GOAL CONTRIBUTION

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INTRODUCTION

Background

In the spring of 1996 NASA Aeronautics embarked on a unique and ambitious planning process. NASA tasked SAIC and its subcontractor, The Futures Group, to develop a scenario-based planning process to address the future of NASA Aeronautics for the next 25 years. Scenario-based planning is a technique for managing uncertainty; not prediction of the future. The intent was not to predict what the Aeronautics market will be and then build a master plan; but rather to ask what the future might hold and identify the actions that might be taken today that will work no matter how the future turns out.

A NASA core team was established to work with SAIC/TFG. This NASA core team and SAIC/TFG met over a period of six months to form the dimensions for the scenario planning process. The results of this effort and a subsequent workshop involving NASA's customers were the basis for five scenarios. These scenarios were then developed with a detailed history, world economic forecasts, socio-political, governmental, and aeronautical industry forecasts. In the fall of 1996 a weeklong government-industry workshop was conducted using these scenarios to develop NASA R&D strategies. Based on the results of this scenario workshop and the ensuing analysis, a number of internal NASA workshop were conducted to develop goals and opportunities for NASA R&D. This was the foundation for the formulation of the NASA Three Pillars and Ten Goals.

In March 1997 the NASA Administrator announced the Three Pillars and Ten Goals for NASA Aeronautics at an Aero Club event in Washington. In October 1998 the NASA Administrator sponsored a meeting to discuss the progress towards these Goals. NASA has developed "Roadmaps" for each of the 10 Goals as a depiction of the milestones and events necessary in the achievement of the goals. The outcome of the October meeting "Turning Goals into Reality" has led toward solidification of the Roadmaps and related milestones.

Purpose

The NASA Program Manager for Information Technology has tasked SAIC to assess the Information Technology (IT) program involvement in the Roadmaps and the IT role in the achievement of the Goals. The purpose of this report is to document the assessment.

DISCUSSION

Approach

The first step in the assessment was to interview the newly assigned IT Program Manager, Dr. Eugene Tu. Dr. Tu supplied the IT Program Plan (Reference 1) and a detailed briefing of the Level 1 program. Next, each of the Level 2 and Level 3 IT Program Managers was interviewed to determine more detailed program information. Table 1 depicts the program organization and identifies the managers.

Once interviews were complete, the second step in the assessment was to analyze the data (Table 2) obtained from the interviews, categorize the data with reference to the Roadmaps and determine if and how the data applied to the NASA Pillars and Goals and the Roadmaps. The Roadmaps (Reference 2) that were used for this report were those presented at the October "Turning Goals Into Reality" Conference and represent the latest NASA version.

The third step was to discuss the findings with the IT Program Manager. After discussions with Dr. Tu, the charts have been finalized for the assessment. See Charts 1 through 10.

Results

There are many technologies within the NASA IT Base Program which could be applied to the Ten Goals' Roadmaps. There are, however, two Goals that this report will focus on due to the number and impact of the applicable technologies: Goal 1—Aviation Safety and Goal 8—Design Tools and Experimental Aircraft.

Goal 1: Aviation Safety

The current IT Base Program supports a new Challenge for this Roadmap: *Developing methods to dramatically reduce the effect of software error by improving software design*. Software is an area where much work is being accomplished within the IT Base Program but isn't being represented to assist in the achievement of the Goals. Currently, there have been accidents caused by mode confusion where the pilot does not understand what the software is doing; this is ultimately blamed on the pilot. There have been over 180 incidents/accidents caused by mode confusion. If those errors were to be eliminated due to reliable, comprehensible software, safety would increase.

Formal Methods of software design could greatly reduce errors in systems. Formal methods are the application of the rigorous techniques of mathematical logic to the specification and verification of digital systems. This provides a means of calculating and hence predicting the behavior of a digital system prior to its implementation, as well as exposing errors early in the design life-cycle. Methods to verify partitioning in integrated systems, methods to demonstrate safety of flight-critical systems, such as digital autopilots, and methods for modeling safety-critical systems requirements and designs, are all areas of investigation by formal methods.

High-Assurance Software Design is investigating and developing tools to increase the integrity and reliability of software for safety-critical and mission-critical flight

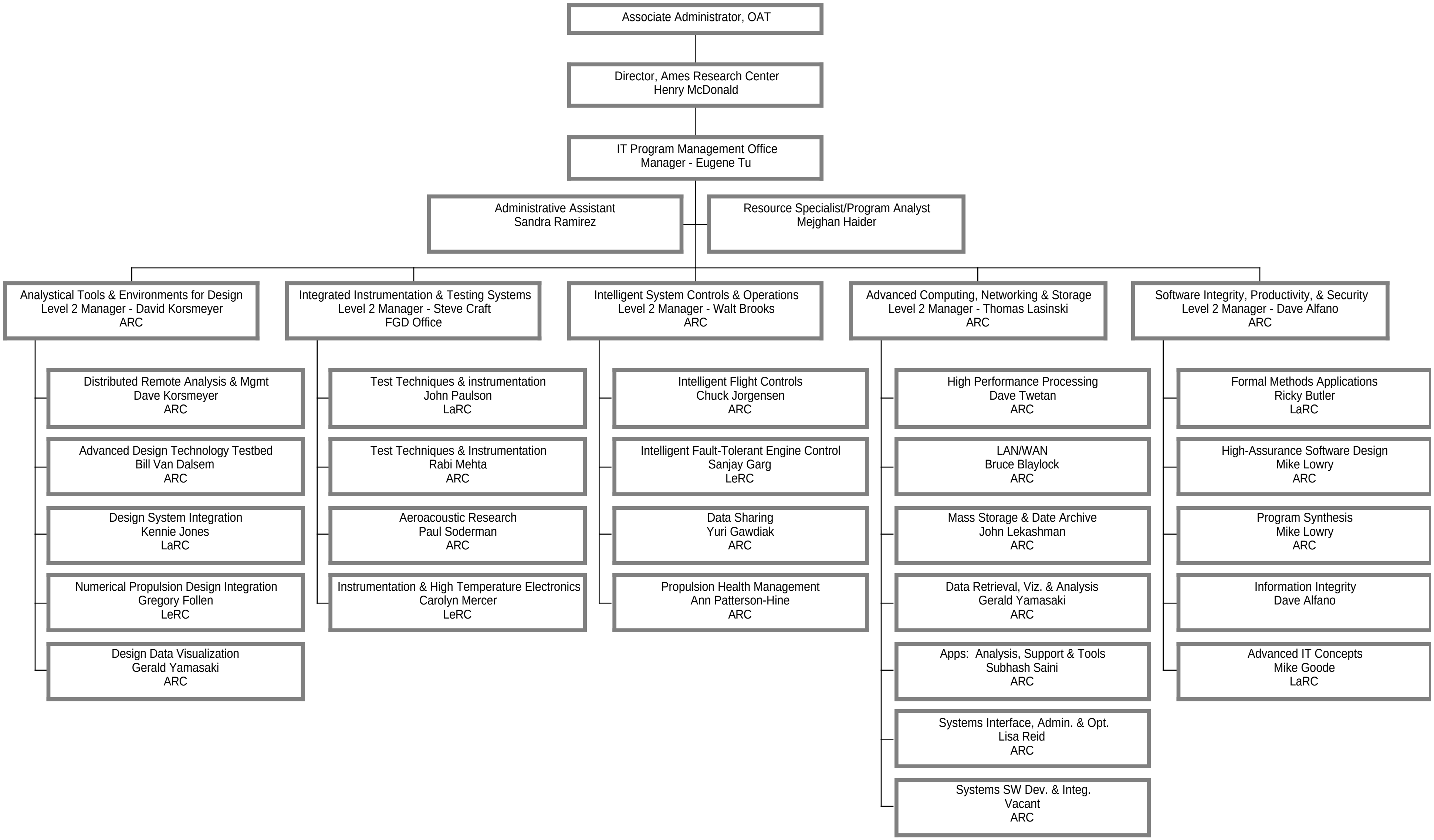

Table 1: IT Base Program Organization Chart

Manager Level 2	**Korsmeyer**					**Craft**				**Brooks**				**Fieierheisen**						**Alfano**				
Level 3	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**
Goals																							*	
1										X		X	2							X				2
2									2		X		2											
3								X	2	2	X		2											
4										2		X									2			
5	X					2					X		X							2	2			2
6	X			2						2			2											
7	2									X	2	X								2				
8	X	X		X	X	X		2		X				2	2	2	2	2	2	X	2			2
9	2	X								X											2			
10																								

Each Level 2 Manager is named as seen in Table 1.
Under each Level 2 Manager is the number of their Level 3 Managers in relation to Table 1.
X=Direct technology application
2=Indirect or secondary technology application

Table 2: Interview Data Analysis Matrix

applications. Emphasis is on scaling-up and automating analytical methods for verification and debugging across the software life-cycle. Analytical methods for increasing the reliability of software in avionics applications hold great promise.

The Outcome on this Roadmap of the above technologies would be the *Elimination of accidents attributable to software*. This is an important issue since the current accident rate is very low. Most proposed improvements, while important, have a minimum effect on accident rate. Elimination of accidents attributable to software will have a major impact on the Aviation Safety Roadmap.

In addition to significant software advances, Advanced Health Monitoring technologies, using sensors located in harsh environments, that provide direct measurements of the quantities of interest, when integrated with photonics-based control architecture and intelligent control algorithms, will allow the aircraft engines to operate safely in the presence of engine subcomponent failures. Intelligent Fault-Tolerant Engine Control (IFTEC) will also enable engine component maintenance to be performed on a need basis rather than on a pre-set schedule basis. This approach will help drastically reduce the aircraft engine maintenance cost and will also reduce the risk of component failures in between scheduled maintenance periods.

Propulsion Health Management is also seen as an area which could greatly affect Aviation Safety. It will identify data characteristics of crucial aircraft turbine engine parameters that can improve the discrimination between an acceptable condition and trends, which are associated with developing faults. Signature analysis, feature extraction methods, fault classification methods and fault libraries will enhance condition monitoring and fault diagnosis for aircraft turbine engines. Trends to be noted by this technology are 1) very short-term noise trends, 2) medium-term trends created by usage patterns, and 3) long-term degradation trends. If engines can be monitored with the intelligence that the trend analyses offer, maintenance will only be necessary when a failure is anticipated (known as condition-based maintenance (CBM)), not when a catastrophe occurs; aircraft will be safer.

Along with the Propulsion Health Management, the Aviation System Monitoring and Modeling project has an objective of exploiting IT resources to capitalize on aviation data. It will 1) identify causal factors, accident precursors and off-nominal conditions in aviation data, 2) provide health performance and safety information to aviation decision makers, and 3) ensure a seamless user-friendly aviation safety database. NASA currently works with its Safety and Capacity Programs, the FAA Technical Center, other government agencies and industry to accomplish this complicated task. By working together, routine monitoring has already discovered errors with technology, which allowed for changes for improvement. Some of those errors are: 1) lower idle thrust of new engines caused low approach speeds, 2) flight management system programs caused altitude ‘busts’, 3) noise abatement procedures caused potential safety issues, and 4) Air Traffic Control (ATC) procedures caused rushed approaches.

So, one can see that the IT Base Program could make a major impact to the Aviation Safety Roadmap if given the opportunity for input.

Goals 2-7: Reduce Emissions of Future Aircraft through General Aviation Revitalization

In all of these Roadmaps, it is recommended that IT be represented by a text line in the large yellow Base R&T arrow because it is a funded base program that has a positive contribution to each of these areas. The most applicable projects that should be represented in the yellow arrow for the different Roadmaps are discussed below:

IFTEC's objectives are to develop and validate advanced instrumentation, health management and control system technologies that are critical to enhancing the safety, reliability and operability of aircraft propulsion systems. If the safety, reliability and operability of aircraft propulsion systems were instrumented in such a way as to monitor the emissions and noise of said propulsion system, those emissions (Goal 2) and noise levels (Goal 3) could feasibly be reduced. With these technology applications, the milestone for reducing or even eliminating CO_2 could probably be moved sooner by 5 years and noise could be greatly reduced.

The Propulsion Health Management project could assist IFTEC with its vibration and trend analyses to accomplish both emissions (Goal 2) and noise reduction (Goal 3). If CBM occurs with propulsion management, then less time will be necessary for tracking maintenance and for aircraft to be down for maintenance, thereby reducing the cost of air travel (Goal 5). Lastly, if propulsion health management can reduce emissions, noise and cost of air travel then, high-speed aircraft design will be more feasible (Goal 6).

The entire Integrated Instrumentation & Testing Systems (IITS) area could reduce noise (Goal 3) if it accomplishes its objective. The objective of IITS is to provide technologies that will facilitate wind tunnel testing, making it one of the primary next generation design tools required to increase design confidence and to cut the development cycle time for aircraft in half. Noise data could conceivably be gathered in the wind tunnel by this instrumentation and utilized to analyze noise data for increased methods of reduction. Also, the reduced design cycle time could save financial resources and help to achieve the Air Travel Affordability Goal (Goal 5).

Distributed Remote Analysis and Management (DReAM) has an objective to increase knowledge and reduce design cycle time and analysis cost by implementing a distributed remote analysis and management information infrastructure architecture to manage and integrate distributed data sources across the Aeronautics enterprise. With this accomplished and data flowing quickly and easily to the pertinent customers, the available data could assist the Air Travel Affordability Goal (Goal 5), the High-Speed Aircraft Design Goal (Goal 6) and the General Aviation Revitalization Goal (Goal 7).

The Advanced Design Technology Testbed (ADTT) project is researching to test new approaches, which will enable the US Aerospace Industry to improve their product development processes. With testing complete, NASA will have the capability as well to reduce their aircraft design cycle time thereby achieving Affordable Air Travel (Goal 5).

The Intelligent Flight Controls project is aiming to develop and flight demonstrate a flight control technique that can effectively identify aircraft stability and control characteristics using neural networks and utilize this information to optimize aircraft performance under a wide variety of accident scenarios. With this technology, a leap might be to take that technology and modify aircraft shape to reduce aircraft noise (Goal 3). With the noise reduced from an aircraft, less drag would be implied, which would mean less fuel burn for flight, which in turn would reduce the cost of air travel (Goal 5). Accomplishing those same objectives, design of high-speed craft would be naturally more easily achievable (Goal 7).

Formal Methods (described in Goal 1) would reduce the cost of air travel (Goal 5). The software required in avionics and other systems would be more reliable and therefore probably less expensive. The systems would be less expensive requiring less maintenance and therefore allow for reduction even more in cost.

Numerical analysis would assist in the design of general aviation (Goal 7) and high-speed aircraft (Goal 6) by setting up an environment to couple Computational Fluid Dynamics (CFD) with experimental data for faster, easier aircraft design. If design were quicker and simpler to accomplish, aircraft would most likely be more affordable (Goal 5).

The above discussion shows the benefits of many different IT projects to several of the NASA Ten Goals' Roadmaps. With the implementation of those technologies, schedules could be moved closer and Goals could more readily realized.

The IT Base Program, however, impacts the Design Tools Roadmap in a major way, as in the Aviation Safety Roadmap. That discussion follows.

Goal 8:Design Tools and Experimental Aircraft

Design Tools is the second Goal Roadmap which could greatly benefit from the IT Base Program technologies. Adding a new Challenge is one way to accommodate the many technologies: *Develop and promulgate software design equivalent to hardware design standards*. To do this, Formal Methods, Software Verification, and High-Assurance Software Design, would be useful. These applications are all described previously.

DReAM (described previously) would also be advantageous for the accomplishment of the Design Tools Goal. The wind tunnel and the almost instantaneous test data retrieval from the wind tunnel would have a major impact on reducing the cycle time for design. This reduction in cycle time for major manufacturers would also trickle down to smaller manufacturers, making large commercial aircraft, as well as smaller general aviation aircraft, less expensive. This tool would make aircraft design faster and easier as well as provide more confident designs thereby helping to accomplish the Goal.

A 10-year deliverable on the Roadmap could be high-fidelity software and systems. The 25-year deliverable would then be virtually error-free software and systems. This line of technologies would then slide down into the Integration line thereby assisting in the Outcome of the Integration Line: Seamless, integrated parallel design processes: analysis-based certification; full life-cycle modeling and optimization; seamless, fully-integrated tools.

Goals 9-10: Space Access

To this point, the technologies within the IT Base Program have focused primarily on Aeronautics. However, from a different perspective, some of the same technologies used for Aeronautics could be applied to the two Space Access Goals.

DReAM's achievement of improved data access speed and reliability would apply here as well. With data flowing almost immediately and accurately to the pertinent customers, the available data could then aid the design of spacecraft, as well as general aviation and high-speed aircraft, and therefore apply to the Low-Cost Space Access Goal (Goal 9).

The ADTT project will enable rapid creation, analysis, and evaluation of alternate high-lift configurations. With this capability, the Low-Cost Space Access (Goal 9) is more reachable.

The Intelligent Flight Controls project will ultimately address the needs for control systems that can be produced and tested at lower cost, and for flight systems that can accommodate damaged control surfaces or changes to aircraft stability and control characteristics resulting from failures or accidents. With this adaptable technology, spacecraft shape could be changed accordingly to reduce drag during liftoff and landing. With reduced drag would come reduced noise and one could infer that the spacecraft would require less thrust to move through orbit.. If the spacecraft required less thrust, it would therefore require less fuel and the cost to send that spacecraft to space would diminish. (Goal 9)

Formal Methods (described in Goal 1) would also reduce the cost of space access (Goal 9) by allowing for more reliable, less risky software design from the beginning. Because there are so many systems for space access, safe, dependable software would greatly improve the confidence of the systems for space access, and most likely curtail cost.

Numerical analysis lastly, assisting in the design of general aviation and high-speed aircraft by setting up an environment to couple CFD with experimental data for quicker, simpler design, could also apply to spacecraft design. If design is virtually effortless and therefore less timely, then the cost to produce said spacecraft would be reduced (Goal 9) from current methods.

Due to the Aeronautics focus of the IT Base Program, technologies don't seem to have an application to the 10th Goal—In-Space Transportation. Possibly at a later date, the technologies being researched could be applied more readily.

CONCLUSION

The objective of this assessment was to research the applicability of the IT Base Program to the 10 NASA Goal Roadmaps and make recommendations. After said research, it can be concluded that the IT Base Program offers significant technologies that impact and offer positive improvement to the Roadmaps. Software-related enhancements could especially affect the Roadmaps for Goals 1 and 8. The IT Program could thus, have a substantial impact on the Outcome of those Goals. The other 8 Goals are also impacted by various IT Program components, but not nearly to the degree of Aviation Safety and Design Tools.

RECOMMENDATIONS

It is recommended that the Roadmaps be modified, at the earlier opportunity, to reflect the conclusions of this report. (Some further discussion among the program managers within NASA is needed to coordinate these proposed Roadmap changes.)